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Anesthetic management in pediatric cardiac reoperations: Experiences from our institution

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Abstract

Aim: Redo cardiac surgery in pediatric patients is associated with increased anesthetic complexity due to adhesions, altered mediastinal anatomy, increased bleeding risk, and arrhythmia susceptibility. Given the scarcity of literature on this high-risk group, this study aims to present our institutional experiences in the anesthetic management of pediatric cardiac reoperations.

Materials and Methods: This retrospective single-center study included 282 pediatric patients who underwent redo cardiac surgery for congenital heart disease between January 2021 and January 2025. Data collected included demographic characteristics, anesthetic techniques, perioperative complications, and postoperative outcomes.

Results: The mean age was 30.82 ± 47.32 months, and 56.02% of patients were extubated in the operating room. In 101 patients (>10 kg), backup femoral sheets were pre-inserted to serve as a guide for potential emergency femoral cannulation during cardiopulmonary bypass (CPB). Intraoperative cardiac or vascular injuries occurred in 4 patients (1.41%), and emergency CPB via peripheral access was initiated in 3 cases. Ventricular fibrillation requiring defibrillation occurred in 18 patients (6.38%), while 3 patients (1.06%) developed supraventricular tachycardia requiring cardioversion. ROTEM-guided bleeding management was utilized in 21 patients (7.44%), with cryoprecipitate and fibrinogen replacement required in 70.21% and 44.32% of patients, respectively. Postoperatively, ECMO was required in 25 patients (8.86%), and the mean ICU stay was 17.18 ± 19.69 days. The overall mortality rate was 12.05%.

Discussion: Redo cardiac surgery in pediatric patients presents considerable anesthetic challenges. Our findings underscore the importance of meticulous preoperative planning, intraoperative vigilance, and targeted hemostatic and arrhythmia management strategies.

Keywords

congenital cardiac surgery, cardiac reoperation, anesthetic management

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Introduction

Patients with complex congenital heart disease often require multiple cardiac interventions and median sternotomies throughout their lifetime. With the increasing life expectancy of this patient population, redo sternotomy has become an increasingly common procedure. Compared to primary cardiac surgeries, the anesthetic management of these patients requires special attention due to a higher risk of complications [1,2]. In patients undergoing redo sternotomy, factors such as adhesions, anatomical alterations in mediastinal structures, arrhythmias, and increased bleeding risk are the main challenges complicating anesthetic care.

During the initial phase of surgery, from skin incision to the initiation of cardiopulmonary bypass (CPB), injuries to cardiac and vascular structures and the phrenic nerve, as well as bleeding and severe arrhythmias, can lead to fatal complications and require meticulous attention. In patients likely to undergo a technically difficult and high-risk resternotomy, peripheral vessels may be used to initiate cardiopulmonary bypass. Several peripheral cannulation sites have been identified, and the femoral vessels have been shown to be safe and effective options for cannulation [3,4]. However, in pediatric patients, the available cannulation sites are limited [5,6]. Due to multiple previous surgical interventions, femoral or axillary vessels may be too small, stenotic, or completely occluded. These limitations can pose challenges for the anesthesia team during preoperative central venous catheterization or when establishing backup peripheral cannulation access. Additionally, due to the risk of severe bleeding, the anesthesia team must be well-prepared in terms of blood products and transfusion management.

Anesthesia departments involved in pediatric cardiac surgery should develop specific approaches and protocols tailored to this high-risk population. However, despite this need, there is a limited number of studies in the literature focusing specifically on this patient group. In our study, we aimed to retrospectively evaluate our institutional anesthesia experience in pediatric patients who underwent redo cardiac surgery between January 2021 and January 2025. By presenting the characteristics of our clinical practice, we seek to contribute to the existing literature and identify potential areas for improvement.

Materials and Methods

This single-center, retrospective study was conducted between January 1, 2021, and January 1, 2025, in the Departments of Anesthesiology and Reanimation and Pediatric Cardiac Surgery at our institution. All pediatric patients who underwent reoperative cardiac surgery due to congenital heart disease were included, regardless of sex.

Exclusion Criteria

- Age over 18 years
- Patients undergoing emergency surgery
- Incomplete or missing data

After obtaining written informed consent, a routine pre-anesthetic evaluation was performed. A total of 282 patients (both male and female) were included in the study.

Out of 450 total patients initially screened, 52 were excluded due to missing data, 17 were older than 18 years, and 99 represented emergency cases. After applying these exclusion criteria, 282 patients met the eligibility requirements and were ultimately included in the final analysis.

Intraoperative Monitoring and Anesthetic Management

Upon arrival in the operating room, all patients were routinely monitored with electrocardiography (ECG), non-invasive blood pressure, and pulse oximetry before the induction of anesthesia. Additionally, due to the increased risk of sudden and serious arrhythmias requiring defibrillation or cardioversion in this patient group, external defibrillator pads were applied, and ECG monitoring was also performed via a separate defibrillator monitor.

As an extra precaution, one unit of erythrocyte suspension (ES) was prearranged and kept available in the operating room in anticipation of severe or massive bleeding. The standard anesthetic induction protocol included:

- Midazolam (0.1 mg/kg)
- Fentanyl (1 µg/kg)
- Ketamine (1 mg/kg)
- Rocuronium bromide (0.6 mg/kg)
- In addition, cefazolin (30 mg/kg IV) and methylprednisolone (3 mg/kg IV) were administered as prophylactic agents. As a non-standard measure, a tranexamic acid infusion (2 mg/kg/hour) was administered in this patient group.

Invasive arterial blood pressure monitoring was established via radial or femoral artery cannulation. Central venous access was obtained through the internal jugular or subclavian vein, or the femoral vein when necessary. In patients over 10 kg, based on institutional consensus between perfusionists and surgeons, backup 5F femoral arterial and venous sheaths were pre-inserted to facilitate emergency femoral cannulation in preparation for cardiopulmonary bypass (CPB). Ultrasound guidance was used for sheath placement, and vessel diameters were measured and documented by the anesthesiology team.

Evaluation Parameters

- Demographic data (age, sex, body weight, diagnosis, prior surgeries)
- Anesthetic agents used
- Duration of anesthesia and CPB
- Perioperative complications (injuries, bleeding, arrhythmias, defibrillation requirements and characteristics)
- Emergency CPB using backup peripheral cannulation
- Excessive bleeding requiring ROTEM-guided intervention, use of the cell-saver
- Postoperative mechanical ventilation, ECMO requirement, ICU length of stay
- Morbidity and mortality rates

Statistical Analysis

Statistical analysis was performed using NCSS (Number Cruncher Statistical System) 2007 (Kaysville, Utah, USA). Descriptive statistics (mean, standard deviation, median, frequency, percentage, minimum, maximum) were used to evaluate the data. The Shapiro-Wilk test and graphical methods were used to assess the normality of distribution. The Mann-Whitney U test was used for between-group comparisons of non-normally distributed variables, and the Wilcoxon Signed Ranks test was used for pre- and postoperative comparisons. Pearson's chi-square test was used to evaluate categorical variables. A p-value < 0.05 was considered statistically

significant.

Ethical Approval

This study was approved by the Ethics Committee of the University of Health Sciences, Türkiye, Basaksehir Cam and Sakura City Hospital (Date: 2025-03-19, No: 103).

Results

A total of 282 pediatric patients who underwent cardiac surgery were included in this study. Among these, 170 (60.3%) were male and 111 (39.4%) were female. The mean age was 30.82 ± 47.32 months; the average weight was 12.23 ± 13.85 kg, and the mean height was 81.21 ± 31.51 cm. The average total anesthesia time was 424.02 ± 116.08 minutes, and the average CPB time was 128.16 ± 78.83 minutes. The demographic and clinical characteristics of the patients are summarized in Table 1. Additionally, 40 patients (14.2%) had a genetic syndrome. A wide variety of complex surgical procedures were performed. The distribution of surgical procedures is shown in Table 2. In 101 patients weighing over 10 kg, 5F backup femoral arterial and venous sheaths were inserted and kept available for emergency use. Intraoperative complications included atrial injury in 1 patient, ventricular injury in 1, pulmonary artery injury in 1, and aortic injury in 1. In 3 of these cases, emergency CPB was initiated using peripheral cannulation and the procedures continued under bypass support.

Due to the high risk of life-threatening arrhythmias, external defibrillator pads were routinely applied, and the ECG was monitored on a separate defibrillator screen. In cases of ventricular fibrillation, defibrillation was initiated at 2 to 4 joules/kg using external pads, and subsequent shocks were applied with gradually increased energy levels. A total of 18 patients (6.38%) developed ventricular fibrillation requiring defibrillation, and supraventricular tachycardia requiring cardioversion was observed in 3 patients (1.06%).

Additionally, one unit of erythrocyte suspension was kept ready in the OR for anticipated major bleeding. In four patients identified preoperatively as high-risk due to extensive adhesions or comorbidities on computed tomography (CT) scans, a cell-saver device was preoperatively set up.

ROTEM-based viscoelastic testing was used in 21 patients (7.44%) due to intraoperative bleeding difficulties. ROTEM® provided real-time assessment of hyperfibrinolysis, dilutional coagulopathy, fibrinogen levels, factor deficiencies, platelet function, and heparin/protamine balance, enabling appropriate blood product replacement. Among all patients, 198 (70.21%) required cryoprecipitate and 125 (44.32%) required fibrinogen replacement.

Pacemaker dependency was noted in 6 patients (2.12%) at the end of surgery. Phrenic nerve injury resulting in diaphragmatic paralysis occurred in 2 patients (0.70%). All complications

Table 1. Demographic and clinical variables for patients

	Mean±SD	Median (Min-Max)
Age (months)	30.82 ± 47.32	10.50 (0.30-216.00)
Weight (kg)	12.23 ± 13.85	7.50 (2.10-88.00)
Height (cm)	81.21 ± 31.51	70.00 (40.00-182.00)
Total anesthesia time (min)	424.02 ± 116.08	415.00(145.00-765.00)
CPB time (min)	128.16 ± 78.83	121.00 (0.00-706.00)
Aortic cross-clamp time (min)	73.23 ± 61.42	67.00 (0.00-278.00)
Hematocrit at surgery start (%)	36.59 ± 6.96	35.75 (23.90-62.50)
Hematocrit at end of surgery (%)	38.32 ± 6.60	37.25 (18.10-54.10)
ICU stay (days)	17.18 ± 19.69	9.00 (2.00-150.00)
	n (282)	**%**
Extubated in the operating room	158	56.02
ECMO	25	8.86
Mortality	34	12.5

*CPB: Cardiopulmonary bypass, ICU: Intensive care unit. ECMO: Extracorporeal membrane oxygenation.

Table 2. Distribution of Surgical Procedures in the Study Population

Procedure	(n = 282)	%
VSD, CAVSD repair	46	16.3
Glenn shunt	33	11.7
Norwood Procedure	32	11.3
Arch reconstruction	25	8.9
Mitral valve repair	22	7.8
Aortic valve repair	19	6.7
Pulmonary valve replacement	18	6.4
Rastelli procedure	14	5.0
Fontan	14	5.0
Tetralogy of Fallot (TOF)	13	4.6
Interrupted Aortic arch	7	2.5
TAPVR	7	2.5
Ross-konno procedure	6	2.1
DORV	4	1.4
Unifocalization procedure	4	1.4
Blalock Taussig (BT) shunt	3	1.1
Others	15	5.3

*VSD;ventricular septal defect, TOF;tetralogy of Fallot, CAVSD;complet atrioventricular septal defect, TAPVR; total anomalous pulmonary venous return.

Table 3. Perioperative complications in pediatric redo cardiac surgery

Complication	n	%
Cardiac and Vascular injury	4	1.41
Ventricular laceration (1)	1	
Atrial laceration (1)	1	
Aortic injury (1)	1	
Pulmonary artery injury (1)	1	
Defibrillation Events	18	6.38
Single defibrilliation required	6	2.12
Two defibrillations required	3	1.6
Three defibrillations required	5	1.77
More than three defibrilliations required	4	1.41
Other Complications		
SVT requiring cardioversion	3	1.6
Emergency CPB with backup peripheral cannulation	3	1.6
Excessive bleeding requiring ROTEM-guided intervention	21	7.44
Pacemaker dependency at the end of the procedure	6	2.12
Nerve injury and diaphragmatic paralysis	2	0.70

*SVT: Supraventricular tachycardia, CPB: Cardiopulmonary bypass, ROTEM: Rotational thromboelastometry

unique to this patient population are summarized in Table 3.

A total of 158 patients (56.02%) underwent fast-track extubation in the operating room. The mean ICU length of stay was 17.18 ± 19.69 days. ECMO support was required in 25 patients (8.86%). Overall mortality was observed in 34 patients (12.05%).

Discussion

Redo cardiac surgery in pediatric patients presents significant anesthetic challenges due to increased surgical complexity, adhesions, altered mediastinal anatomy, heightened bleeding risk, and a greater susceptibility to arrhythmias. In our study, we retrospectively analyzed the anesthetic management of 282 pediatric patients who underwent redo cardiac surgery and identified key perioperative considerations and complications that necessitate meticulous preparation and a multidisciplinary approach.

One of the most critical aspects of redo sternotomy is the risk of vascular and cardiac injury during re-entry. Previous studies have reported an increased incidence of major vessel injuries, particularly in patients with extensive adhesions from prior surgeries [7,8]. In our series, major vascular injury involving the atrium, ventricle, pulmonary artery, or aorta occurred in 4 patients (1.4%). This rate is consistent with previously reported incidences ranging from 1% to 5% [9]. In three of these cases, emergency cardiopulmonary bypass (CPB) was initiated via femoral cannulation guided by pre-prepared reference sheets, underscoring the importance of having peripheral vascular access readily available in high-risk patients. Previous studies have demonstrated that femoral cannulation is a safe and effective strategy in pediatric reoperations where central cannulation poses a high risk [3,4].

Bleeding remains a major challenge in redo pediatric cardiac surgery, often necessitating intraoperative transfusion and hemostatic intervention. In our study, excessive bleeding requiring ROTEM (rotational thromboelastometry)-guided hemostatic therapy was observed in 21 patients (7.44%), highlighting the importance of point-of-care coagulation monitoring. Prior studies have shown that ROTEM can improve targeted transfusion strategies, minimize unnecessary blood product use, and help prevent dilutional coagulopathy [10-13]. Moreover, a significant proportion of patients required cryoprecipitate (70.2%) and fibrinogen replacement (44.3%), reinforcing the need for proactive blood management protocols.

Another important concern in redo cardiac surgery is the increased incidence of arrhythmias, which may require defibrillation or cardioversion. In our cohort, ventricular fibrillation requiring defibrillation occurred in 18 patients (6.38%), while supraventricular tachycardia necessitating cardioversion was observed in 3 patients (1.06%). These findings are consistent with existing literature suggesting that reoperations elevate the risk of intraoperative arrhythmias due to previous scarring and conduction system disturbances [14]. As implemented in our study, the routine placement of external defibrillation pads and continuous arrhythmia monitoring may be recommended for this patient population.

In recent years, fast-track extubation has been advocated in pediatric cardiac surgery cases, with several studies supporting its feasibility [15-18]. In our study, despite the complexity of the pathologies and the fact that the patients underwent redo surgery, the majority (56.02%) were extubated on the operating table. Notably, none of these patients required reintubation. The feasibility of fast-track extubation even in these complex redo cases is promising for increasing fast-track extubation rates in primary congenital heart surgeries as well.

Postoperative outcomes in our study revealed prolonged intensive care unit (ICU) stays (17.18 ± 19.69 days) and the need for extracorporeal membrane oxygenation (ECMO) in 25 patients (8.86%). In the study by Yin et al. [19], ICU stay duration was also reported to be longer in redo cardiac surgeries compared to initial surgeries. The overall mortality rate in our cohort was 12.05%, which is within the range reported in previous studies on complex congenital heart diseases requiring reoperation [20,21]. These findings highlight the need for optimized perioperative strategies to improve long-term outcomes in this vulnerable population.

Limitations

This study is limited by its retrospective, single-center design, which may restrict the generalizability of the findings to other institutions or populations. Additionally, the absence of a control group and potential confounding factors inherent in retrospective data collection may have influenced the observed outcomes.

Conclusion

Our study emphasizes the challenges of anesthetic management in pediatric redo cardiac surgery and highlights the importance of meticulous planning, intraoperative vigilance, and targeted hemostatic and arrhythmia management. Future prospective studies and multicenter collaborations are essential to further refine perioperative approaches and improve clinical outcomes in this high-risk group of patients.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content, including study design, data collection, analysis and interpretation, writing, and some of the main line, or all of the preparation and scientific review of the contents, and approval of the final version of the article.

Animal and Human Rights Statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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